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DRINKING FROM THE FIRE HOSE: Why the Flight Management System Can Be Hard to Train and Difficult to Use

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Summary

The Flight Management Computer (FMC) and its interface, the Multi-function Control and Display Unit (MCDU) have been identified by researchers and airlines as difficult to train and use. Specifically, airline pilots have described the "drinking from the fire-hose" effect during training. Previous research has identified memorized action sequences as a major factor in a user's ability to learn and operate complex devices.

This paper discusses the use of a method to examine the quantity of *memorized action sequences* required to perform a sample of 102 tasks, using features of the Boeing 777 Flight Management Computer Interface. The analysis identified a large number of memorized action sequences that must be learned during training and then recalled during line operations. Seventy-five percent of the tasks examined require recall of at least one memorized action sequence. Forty-five percent of the tasks require recall of a memorized action sequence and occur infrequently. The large number of memorized action sequences may provide an explanation for the difficulties in training and usage of the automation. Based on these findings, implications for training and the design of new user-interfaces are discussed.

Introduction

Investigations into modern flight-deck operations have identified the complexity of training and using functions provided by the Flight Management Computer (FMC) and it's the Multi-function Control and Display Unit (MCDU). Pilots described the experience of learning to use this automation as "drinking from a fire hose" (BASI, 1999; page 38), and only achieve skilled and efficient use of the system after 12 to 18 months of line experience (Polson, et al., 1994). Several studies and surveys of pilots have consistently revealed that pilots have difficulty in using the features of the MCDU during line operations due to gaps in their knowledge (Mumaw, et. al. 2000; ATA 1999; FAA 1996; Feary et al. 1998) and cite the need for more training (ATA, 1999a, BASI 1999; page 38).

Issues with training and using the FMC/MCDU have been attributed to the lack of a detailed conceptual understanding of how traditional pilot tasks are performed by the FMS/MCDU (Sarter & Woods, 1992; Bobbitt, 2001). Other researchers have discussed the awkward layout of the keyboard (Sarter & Woods, 1994), the number of pages and features (Billings, 1997), the complexity of navigating through the hierarchy of pages (Abbott, 1997), and the inefficiencies in inputting data (Casner, 1994).

Whereas all these phenomena contribute in varying degrees to the perceived complexity of the device, there is mounting evidence (Wharton et al., 1994, Franzke, 1995, Irving et al., 1995, Anderson et al., 1998, Soto, 1999) that the number of memorized action sequences that must be learned and then recalled during high-tempo, safety critical line-operations is a prime determinant of the ease of training and operation.

This paper describes an analysis of a sample of 102 airborne tasks that can be performed using functions supported by the MCDU as described in a standard B777 FMS Pilot's Users Guide (Honeywell, 1995). The analysis identified a large number of memorized action sequences that must be learned during training and then recalled during line operations. Seventy-five percent of the tasks examined require recall of at least one memorized action sequence. Forty-five percent of the tasks require recall of a memorized action sequence and occur infrequently. This dependence on memorized action sequences provides a possible explanation for the difficulties in training and usage of the automation. Based on these findings, implications for training and the design of new user-interfaces are discussed.

Pilot-Automation Interaction Performance

Human-automation interaction can be modeled by a two-way communication between operator and automation (Billings, 1997). The operator communicates intentions to the automation using input control devices on the user-interface. The automation acknowledges pilot commands and provides feedback of its commanded behavior and the changes in the environment over time through the user-interface. The interaction with the automation (and much other human behavior) is considered to be a continuous process of cyclic interaction (Monk, 1999) that is the basis for all modern models of cognition (e.g. Card, Moran, & Newell's (1993) recognize-act cycle, Norman's (1998) seven stage cycle, and Anderson's (1998) ACT-R model). In the case of the aircraft automation, triggering events in the environment (e.g. ATC instruction) cause the pilot to formulate tasks that are performed using functions supported by the automation. Commands from the automation modify the airplane trajectory (or other airplane system states) that leads to changes in the environment, that trigger new events, that lead to the formulation of new tasks, and so on.

The RAFIV Method for Decomposing Automation Tasks

The formulation of a task by a pilot in response to an external triggering event and the sequence of pilot actions to command the automation can be modeled using a series of five stages (Sherry, et al., 2002). The RAFIV method is illustrated in Figure 1.

1. Reformulate the task into a definition of the function (or feature) of the automation that will be used, and the data defined by the task (Palmer et al., 1992). For example, an ATC clearance direct to waypoint can be executed using the DIRECT TO feature of the MCDU. In this example, the waypoint is the data that must be entered. To complete the task, the pilot will need to have waypoint information available (in this case the waypoint information is provided in the ATC clearance).

Once a description on how to use the automation has been defined, the pilot must perform actions to transfer the description to the automation via a sequence of actions. These actions have been divided into three steps by Polson, Irving, Irving (1995).

2. **Access** the right user-interface by physical actions that must be taken on the user-interface to display the fields for data entry by selecting MCDU mode keys and/or navigating the hierarchy of pages on the MCDU.

3. **Format** data for entry according to the formats accepted by the MCDU pages. For example, the entry of a lateral route offset on the MCDU is <Side L or R><distance in nm.>. Most formatting takes place while typing entries into the scratchpad.

4. **Insert** data in the correct location. For example Line Select keys on the MCDU used to select items and insert data typed into the scratchpad.

The format and insert stages maybe repeated several times for multiple entries (e.g. Hold page).

Verify & Monitor that the automation: (1) accepted the pilot entry, (2) is performing the intended task within the envelope of acceptable performance, and (3) the task is satisfying the mission goals (Fennell, 2002). This step involves scan and intensive scrutiny of the PFD, ND, and MCDU.

Pilot Performance Executing RAFIV steps.

Each of the stages of the RAFIV model are performed by the pilot by some combination

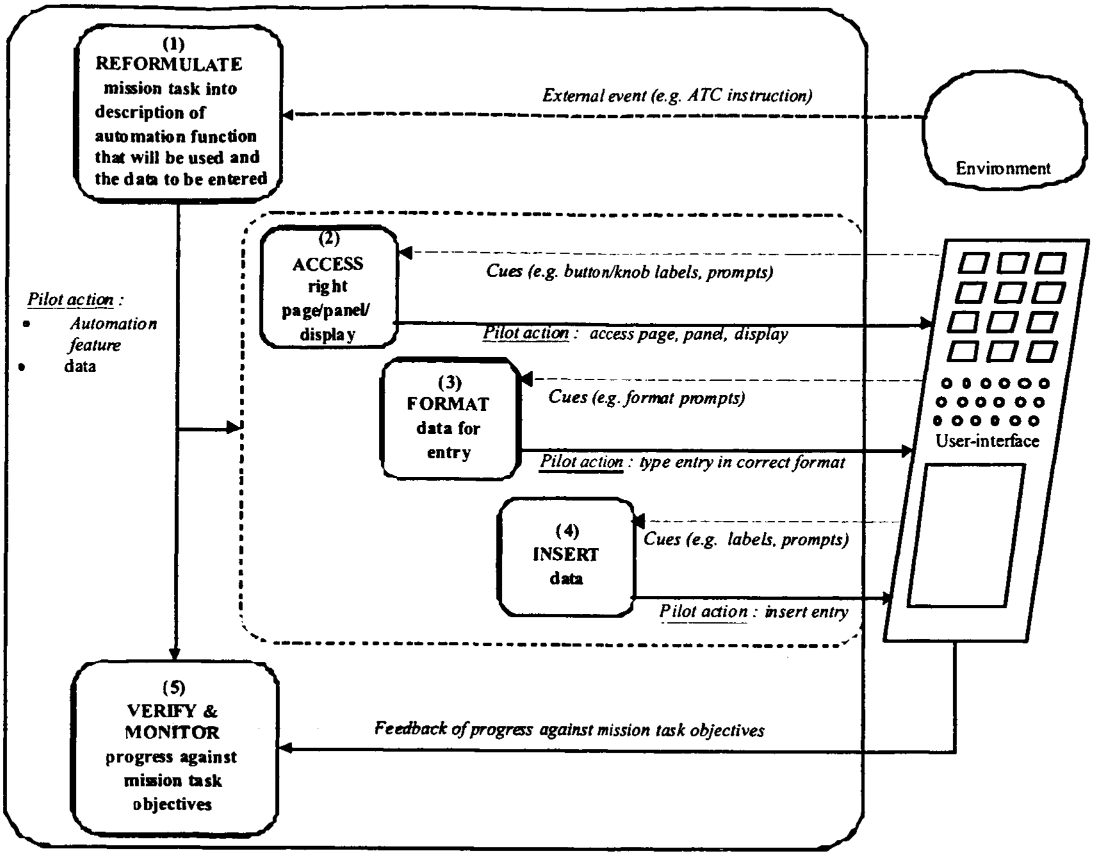

Figure 1. Pilot's Cognitive Task Steps.

of: (1) *recalling* the appropriate action sequence from long-term memory, and by (2) *recognizing* the appropriate action sequence from salient visual cues in the environment (e.g. button label or prompt on the user-interface).

Pilot Performance during Line Operations

Studies of office automation found that infrequent tasks that are not prompted by salient visual cues exhibit a less than 50% probability of being completed (Franzke, 1995; Soto, 1999). Aircraft automation tasks that are frequently performed by recall of memorized action sequences become so over-learned that they become rote and are completed properly approaching 100% of the time. Infrequent tasks that are prompted by salient visual cues (e.g. labels) rely on recognition of the appropriate action and are also completed properly close to 100% of the time. *Tasks performed infrequently (less than once a month), that rely on the recall of memorized action sequences (i.e. no salient visual cues), are likely to be forgotten by pilots, and lead to the perceived complexity in operating the MCDU/FMS.*

Pilot Performance during Training

The training of pilots to operate FMC systems involves the memorization of action sequences for each stage of each task. The ability to recall memorized action sequences is created through training by creating appropriate knowledge structures in long-term memory. This skill can only be developed through drill and practice. *Visual cues, such as labels and prompts on the user-interface play a big role in speeding up the process of memorizing action sequences for the MCDU.* Data from the study of office automation shows that training tasks without visual cues (e.g. labels, prompts) can take 2 to 10 times longer to reach competence, than training tasks with visual cues (Wharton et al., 1994).

Summary

Tasks that rely on memorized action sequences (not recognition of visual cues) are error prone and require more time to master during training. Tasks that occur infrequently and rely on the recall of memorized action sequences are subject to failure due to the failure to recall the correct action sequence.

The purpose of this study is to analyze tasks performed by the FMC/MCDU to determine the degree of reliance on memorized action sequences. An overwhelming reliance on memorized action sequences accounts for some of the difficulties in training and using the automation experienced by airline pilots.

Method of Analysis

A sample of 102 airborne tasks defined in the Honeywell B777 Pilots Guide (Honeywell, 1995) were analyzed. Each mission task was described using the 5 stage RAFIV model. Each task was classified as Frequent or Infrequent. Each RAFIV step of the task was classified as Recall or Recognition based on the existence of salient visual cues to aid in the performance of the step. A step without any visual cue was designated as requiring the recall of memorized action sequences.

Task Selection

The tasks used in the analysis were MCDU tasks defined in the B777 Pilots Guide developed by Honeywell (Honeywell, 1995). Since this manual is a "system description," the tasks were culled by parsing the manual section by section and pulling out descriptions that were associated with the pilot performing tasks using the MCDU. Only airborne operations tasks were included.

Team

The tasks were classified and analyzed to criteria by the team of authors that included; one flight instructor at a major U.S. airline with 16 years experience, one senior cognitive scientist with over 40 years experience, one twin jet-engine rated pilot who is also a human factors researcher with 10 years of experience, and one avionics design engineer with 18 years experience designing these systems. All classifications of the tasks were made by concurrence of all parties.

Criteria for Classification of Recall/Recognition for each RAFIV Step

The RAFIV steps described each FMS/MCDU task. Each RAFIV step was catalogued as either requiring recall of memorized action sequences, or using recognition of visual cues on the automation.

A <u>reformulate step</u> was classified as a *recognition* stage if the user-interface provided a visual indication that the task:

1. could be performed using a feature the automation (and not broken down into several sub-tasks for indirect application of several automation features).

2. the data (e.g. ATC instruction) could be entered directly without mental computation (e.g. compute reciprocal).

3. the automation feature was labeled and visually salient.

That is, an ATP certified pilot without experience using the automation could figure out how to perform the task using the automation by trial-and-error (under the assumption of shared terminology).

A reformulate stage that required mental calculation of parameters, knowledge where the function was "hidden" in the automation displays, and/or a deep understanding of automation unique representations was classified as *recall.*

An <u>access step</u> was classified as a *recognition* stage if the input device to access the feature was clearly labeled or prompted. Otherwise

Table 1. The RAFIV steps for execution of the lateral route offset task on B777 (Honeywell, 1995 page 3.4-28).

Pilot Task: ATC: "For traffic, offset 20 miles left of current flightplan" **(Infrequent)**

	Reformulate	**Access:**	**Format:**	**Insert**	**Verify & monitor:**
Step	Offset Active Route 1 by 20 miles to the left	MCDU Route page	Type in the scratchpad <side L or R><distance in nautical miles>	(1) LS 6R, (2) Execute	
Class.	**RECALL: Pilot must remember offset is manipulation of the route (not legs). Also, offset applies only to certain portions of the route (e.g. not on published STAR, etc...)**	Recognition: Mode key labeled RTE	**RECALL: Pilot must remember format <side L or R><distance>. Also, pilot must remember distance is limited to 99nm. Error message "INVALID FORMAT"**	Recognition: LS 6R labeled "OFFSET	Recognition: ND provides good information to confirm the entry, and monitor the progress.

the stage was classified as a *recall* stage. For example an appropriately labeled mode key or line-select prompt provided visual cues for a recognition classification.

A *format step* was classified as a *recognition* stage if the format for data entry was displayed (e.g. labeled field, default values, list of options). If the stage required recall of the format, then the stage was classified as *recall.*

An *insert step* was classified as a *recognition* stage if the location of entry was labeled. Otherwise the stage was classified as *recall* stage.

A *verify and monitor step* was classified as a *recognition* step if the automation provided feedback that confirmed the progress toward the task goals. Although the ND and PFD provide the major source of task feedback, this study limited analysis to the feedback on the MCDU. The step was classified as a *recall* step if the step required mental calculation of parameters, knowledge where the function was "hidden" in the automation displays, and/or a deep understanding of automation unique representations to verify and monitor the task.

Frequency Criteria:

Tasks were classified as frequent if they occurred at least once a month. Given a typical long-range utilization of a B777, a typical B777 airline pilot will fly approximately 10 legs per month. As a consequence, tasks were classified as frequent

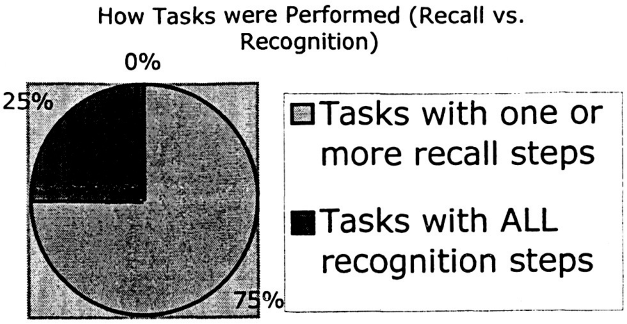

Figure 2. 75% of the tasks include at least one recall step. This places tremendous emphasis on memorization as a skill to get through training.

if they occurred on average once in every ten flight legs. Tasks were classified as infrequent if they occurred once in every ten flights or more (i.e. less than once a month).

Example RAFIV Analysis

The RAFIV steps for execution of the lateral route offset task on B777 (Honeywell, 1995 page 3.4-28) are summarized in Table 1. Row 2 describes each RAFIV step for this task, and row 3 includes the Recall/Recognition classification for each step

Results of Analysis

A total number of 102 tasks were found in the airborne section of the Honeywell B777 Pilot's Guide. A complete list of the tasks is included in Appendix A.

There are three major findings.

1. 75% of the tasks include one or more steps that require recall of memorized action sequences (see Figure 2).

2. 60% of the tasks require recall for the Reformulate step, 45% for the Access step (see Figure 3).

3. 45% of the tasks are classified as infrequent (occurring less than once in a month of flying) AND require recall of memorized action sequences (see Figure 4).

Explaining Training Difficulties

Seventy-six of the 102 tasks included one or more steps that require recall of memorized action sequences. The implication of this result is that 3/4 of the tasks cannot be trained to competence without mastering at least one memorized action sequence. *This places tremendous emphasis on memorization as a skill to get through training.*

Furthermore, memorizing action sequences cannot be achieved simply by watching a CBT and/or with free-play on a simulator. Memorized action sequences require mnemonic devices and other memorization techniques to train effectively. Proficiency can only be obtained through drill and practice. Computer-based-training (CBT) devices and free-play simulators are not designed to effectively develop these skills.

Figure 3 illustrates the breakdown between the RAFIV steps reliance on recall of memorized action sequences. The reformulate step, for 60% of the tasks, required recall of the existence of the feature in the hierarchy of MCDU pages, a significant modification of the task into different or smaller sub-tasks, and/or mental computation of a parameter. *Training of this skill involves explicit memorization of the mapping between ATC instructions and other pilot tasks to the*

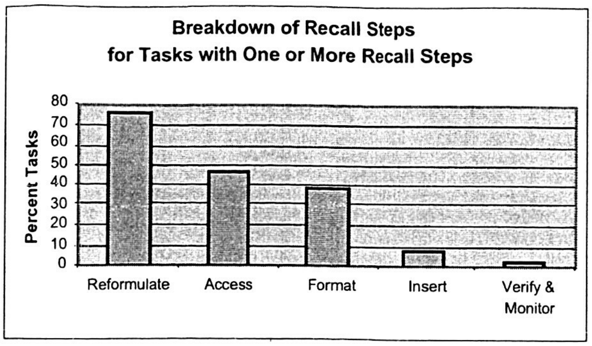

Figure 3. Memorization is required to perform the Reformulate and Access steps.

features of the automation. Because this information is not saliently visual on the automation it must be trained explicitly.

This result is a conservative estimate as this study considered only tasks that can be performed directly by the automation. There are many other tasks, which the automation can be made to perform, but these were not listed as such in the manual and therefore were not considered for the purposes of this investigation.. For example, the BASI report (1999, page 64) found that 42% of the pilots indicated that they are required to enter "workarounds" (intentionally incorrect or fictitious data) to ensure that the system did what they wanted it to do. This problem occurred more frequently when pilots were trying to comply with "difficult air traffic control instructions and to compensate for inadequacies during the descent/approach phases of flight."
Forty five percent of all tasks required recall to access the correct page. This is a consequence of the limit of using 11 mode keys to access features. There are two main classes of access mode keys, those that access functions, and those that access underlying representations that can be manipulated. The PROG, HOLD, DEP/ARR and ALTN mode keys provide access to functions for performing these tasks. The RTE and LEGS Mode Keys provide access to representations of the flightplan that can be manipulated in several different ways. Mode keys labeled with task names were considered Recognition. Mode keys labeled with representations of the flightplan generally were classified as Recall (unless the ATC instruction included the phrase akin to "route" or "leg"). For example, the fields that accept the entries for an offset to the lateral path are located on the RTE page. Pilots in training and line pilots were observed to access the LEGS page when asked to perform this task. (Fennell, 2002). *Training of this skill involves explicit memorization of the navigation from mode keys and Line Select prompts through the hierarchy of MCDU pages.*

The format step also requires recall of memorized action sequences in support of entry of data whose format is not annunciated on the display. For example, programmed step climb points are entered with format "/<flightlevel>S." The absence of the slash or S will result in failure to complete the task. Most of the tasks classified as Recall for the format stage involved multi-parameter entries in which order, acronyms, and partitioning (e.g. "/") were required. The other format problems were with the use of acronyms. *Training of this skill involves explicit memorization of the special case formats.*

The issues associated with format of entries are compounded by ambiguous feedback from the automation when there is a format error (e.g. INAVLID ENTRY or FORMAT ERROR). Pilots in the BASI report specifically cited these scratchpad messages as a source of confusion and suggested that they provide better feedback "to lead the pilot to the source of the problem." (BASI 1999, page 60)

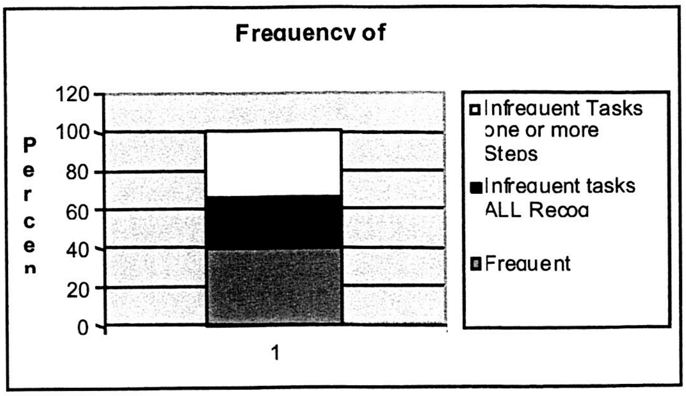

Figure 4. Infrequent tasks with one or more recall steps (45%) are likely to be forgotten without recurrent training.

The FMC/MCDU had very few issues with the Insert step. Problems were the result of the absence of labels. For example, the location for insertion of the Direct To waypoint is not labeled. *Training of this skill involves explicit memorization the special case insertions.*

As discussed in the methods section above, the Verification and Monitor step was limited to an analysis of the verification of acceptance of the pilot entries on the MCDU and did not include feedback from the PFD and ND. The FMC/MCDU had very few issues with the Verification and Monitor step. Problems were the result of the absence of feedback of the status of the automation. For example, if an abeam point cannot be computed on the flightplan, the only feedback to the operator is the cryptic INVALID ENTRY message. *Training of this skill involves explicit memorization of the responses to special cases.*

Explaining Operational Difficulties

Forty-six tasks, (45%) were classified as infrequent (occurring less than once in a month of flying) and require recall of memorized action sequences. Without proficiency training there is a high probability that these skills, once trained will erode. Pilots flying-the-line are likely to experience difficulty in remembering how to perform a task that they have seen before but not used in recent months. *These tasks must be retrained on a periodic basis to maintain proficiency.*

Discussion

The results of this study have implications for the way this automation is trained, and on the way future generations of the automation should be designed and certified. It should be noted that the source of the tasks used in this study was the equipment manufacturer's Pilots Guide, and these tasks include only those that the automation is directly designed to support. Tasks that are not directly supported by the automation, but which end-users may perform, were not considered. As a consequence, the percentage of tasks requiring reformulation is almost certainly a conservative estimate. In light of the source of task information, the following results are even more interesting.

- **76 of 102 tasks (75%) required memorization of at least one step to complete the task**. These tasks can be seen as contributing to the "drinking from a fire-hose effect" experienced by pilots during transition training (BASI, 1999; page 67)

Table 2. Specific skills to be emphasized for each of the RAFIV steps

RAFIV Step	Specific Skill Emphasized
Reformulate	**Explicit memorization of the mapping between ATC instructions and other pilot tasks to the features of the automation.**
Access	**Explicit memorization of the navigation from mode keys and Line Select prompts through the hierarchy of MCDU pages.**
Format	**Explicit memorization of the special case formats.**
Insert	**Explicit memorization the special case insertions.**
Verification and Monitoring	**Explicit memorization of the responses to special case verification.**

- **46 of 102 tasks (45%) are performed infrequently and require memorized actions sequences.** This directly contributes to the perceived gaps in pilot knowledge during line-operations and the desire for more training to maintain proficiency (ATA, 1999a).

The results of this analysis provide an explanation for why pilots find the FMC and MCDU difficult to learn and difficult to use. Tasks performed using the FMC/MCDU require a heavy reliance on memorized action sequences. This has implications for training and for line operations.

Pilot Training of Existing Equipment

The results of this study emphasize the need to provide pilots with a means of mitigating the issues that arise from the large proportion of memorized action sequences existing in current FMC/MCDU designs. Based on the RAFIV model, proposed training programs should:

1. provide explicit models of the skills required to perform tasks using the automation

2. provide schemas that organize and make comprehensible these skills

3. provide schemas that support the transfer of training from one skill to the next

4. train the required memorized action sequences.

The first objective of training is to provide explicit models of the skills required to perform mission tasks. A mission task is defined as a task which directly supports an operational goal (e.g. an air traffic control clearance). These are compared with other user tasks which a user must perform to enable the automation to operate correctly (e.g. entering preflight data in the automation). An example of a model that should be introduced and trained is the RAFIV model. It provides the foundation for organizing and remembering the procedures for specific tasks. Table 2 summarizes the skills for each step in the RAFIV process.

The RAFIV model also provides the basis for schemas that organize and make comprehensible the required skills based on the general characteristics of the user-interface. Each step in the RAFIV process exhibits common skills and conventions across tasks. For example, the Access step is always performed via a Mode key or a prompted Line Select. The conventions associated with the Mode keys and the conventions for accessing pages from prompted line selects can be explained up-front and reinforced throughout the training. Exceptions to these conventions should be identified explicitly. Novices will rarely discover these underlying common structures and are likely to treat two closely related skills independently and not take advantage of the transfer of skills between tasks, unless these common elements are explicitly identified and trained.

As shown by this study there is a lot of information that must be memorized to become a skillful user of the automation. The training program must face this fact and make the memorization process as efficient as possible. For tasks that rely on visual cues, the explicit models must include information on where to look and how to recognize the visual cues. For tasks that rely on memorized action sequences, well designed training must support learning the memorization steps with appropriate mnemonics and appropriate drill and practice. Table 2 specifies the areas of specific emphasis required for each of the RAFIV steps.

Finally, the tasks themselves can be grouped according to the basic underlying structure of the action sequences. These tasks are then trained with incrementally increasing "grain size." The first task may be trained to criteria pointing out all of the components but not introducing the complete abstract schema. Then the second task, superficially different to the first task but sharing the same schema is trained by corresponding elements to the first task. One can then introduce the schema explicitly. The remaining tasks are then trained according to the underlying schema.

Blackmon and Polson (2002) describe proposed training devices that merge three technologies to increase efficiencies in training: (1) part-task (desktop) simulators (2) cognitive tutors (Anderson, 1998), and (3) explicit task RAFIV models that identify recall and recognition steps. The utility of these ideas have been demonstrated by Polson, Irving & Irving (1994) and Sherry et al. (2001).

Pilot Proficiency In Using Existing Equipment

Pilot proficiency during line operations for infrequent tasks that rely on memorized action sequences can only be maintained through practice. This could be accomplished using the training approach described above. Fennell (2002) has proposed developing a curriculum that allows pilots to practice infrequently used skills during long-range cruise operations.

Design and Evaluation of New Equipment

New flightdeck systems should be designed with user interfaces that minimize the need for memorized action sequences. For frequent tasks, this will minimize training time. For infrequent tasks this will minimize training time and improve line operations performance.

Based on this study, it appears that design engineers with no formal cognitive science training can use the RAFIV method to conduct cognitive usability analysis.

A critical element of introducing the method is the definition, and use throughout the life cycle, of a master description of the mission tasks that the system is designed to address. Mission tasks that are not supported should be explicitly classified as such. All downstream process documents, code and tests must reference through a traceability matrix back to these tasks.

Furthermore the specific design of the user-interface to maximize the cognitive efficiency can be developed through a process that is outlined below (Sherry, et. al., in work)

1. Define the mission tasks

2. Define the data required to perform the mission tasks

3. Design user-interface elements for each task (including required data). This may include development of representations of the environment which can be manipulated (e.g. route) See Vicente (1999) for specific approaches.

4. Organize these interface elements to maximize the efficiency for access and provide salient visual cues

5. Provide salient visual cues (e.g. pull-down menus) for the formatting and insertion of all data

6. Provide feedback of the state of the task. This is related closely with step 3.

The vendors of avionics equipment have responded to demand for improved cockpit operations by implementing graphical user-interfaces. Graphical user-interfaces on the flighdeck do not inherently address the issues of Reformulation, Access, Format, and Insertion, although several of the features generally associated with graphical user-interfaces invoke the recognize (not recall) paradigm. These user interfaces exhibit strengths and weaknesses with respect to the RAFIV steps.

Graphical user-interfaces can provide a more intuitive scheme for enabling pilots to perform mission tasks directly with the automation without excessive reformulation. Graphical user-interfaces also encourage visual representations of the environment (e.g. graphical flightplans). They provide the means for a "canvas" on which objects can be manipulated, and a "palette" of manipulations that can be performed. This can provide a user-interface in which representations of the environment are presented on the automation interface (e.g. aero charts on the Navigation Display). Additionally, if the objects in the user interface can be directly manipulated to reflect the clearance or pilot task, reformulation of the task is minimized.

Wizards and dialogue boxes are alternative means for aiding the reformulation process. A task that is decomposed into sub-tasks can be managed by entries through a multi-step wizard. Likewise, Dialog boxes provide a list of entries for a given task. The HOLD page on existing systems is an example of a Dialog box.

Access remains a problem even with graphical user-interfaces. The capacity of the available user interface space for access input devices (e.g. mode keys) could be quickly reached as the number of functions provided by the automation grows. Organizing tasks by task-type or manipulation-type requires the user to master a model of this organization.

The application of pull-down menus, and dialog boxes, can significantly simplify and eliminate errors in the access, format, and insert actions.

It should be noted that the success of any graphical user interfaces for the flightdeck lies in the abilities of the designers *to understand the mission tasks and provide automation to support the pilot in executing these tasks.* Once this has been accomplished, the design of the user-interface should address Access, Format and Insert issues.

This paper discussed the use of a method to examine the quantity of *memorized action sequences* required to perform a sample of 102 tasks, using features of the B777 MCDU. The analysis identified a large number of memorized action sequences that must be learned during training and then recalled during line operations. Seventy-five percent of the tasks examined required recall of at least one memorized action sequence. Forty-five percent of the tasks required recall of a memorized action sequence and occur infrequently. It has been proposed that the disproportionate number of memorized action sequences may provide an explanation for the difficulties in training and usage of the automation.

This paper has also illustrated possible solutions to the FMC/MCDU training and operational difficulties based on the RAFIV method. Future work will include evaluation of the potential of these solutions.

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APPENDIX A

RAFIV Steps for B777 Mission Tasks with Recall/Recognition classification and Frequent/Infrequent Classification. All tasks were identified from Honeywell (1995) Boeing 777 Flight Management System Pilot's Guide. Honeywell Publication # C28-3641-22-00.

LEGEND:

Task No.	Task	Reformulate	Access	Format	Insert	Verification
Freq/ Infreq	Notes on task	Recall/Recognition of Reformulate step	Recall/Recognition of Access Step	Recall/Recognition of Format Step	Recall/Recognition of Insert Step	Recall/Recognition of Verification Step

1	Initiate takeoff roll	Advance throttles to Takeoff EPR reference by 50 knts CAS. Pilot adv throttles slowly and smoothly to approx 1.05 EPR and allow EGT stabilize, then press TOGA switch. Once TMCF set thrst lvl and ac spd reaches 80 knots, cntrl of thrttles is relinquished until 400 ft	NA	Advance throttle levers	NA	EPRs advance, plus other stimuli
		Recall: Task is supported indirecty by automation. Several steps require timing and memorized action sequence				Recog:
2	Reduce thrust from Takeoff thrust to Climb thrust at thrust reduction altitude	Press THR button on MCP. If VNAV is not engaged, thrust is reduced at the thrust reduction altitude by pressing the THR button on the MCP. If VNAV is engaged, thrust is automatically reduced at the thrust reduction altitude (typically 1000' AGL).	NA	NA	Press THR Button on MCP	FMA= THR REF, verify target EPR. EPRs decrease, plus other stimuli

	Task is normally done by FMC (not manually). When doen by the FMC must be monitored.	Recall: Task is supported indirectly by the automation. Data Thred Alt. Function not visually salient. Overloaded button.			Recog: Button labeled THR	
3	Change CRZ ALT	Enter new CRZ Alt on CLB page	VNAV Mode key (Prev or Next)	Type altitude into scratchpad	1L	MCDU page changes
		Recall: Task is supported by the automation. Data is defined by clearance. Function is NOT visually salient. [CRZ Alt can be entered on MCDU, or by dialing a new alt into the MCP (provided no intermediate constraints exist betwn current alt and MCP Alt)].	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog: Valid entries are standard altitude entries. Default entry exists on VNAV CLB page	Recog: Labeled CRZ ALT	Recog:
4	Select new climb speed (CAS or Mach)	Enter new CAS or Mach on CLB page	VNAV Mode key (Prev or Next)	Type CAS, Mach, CAS/Mach, or Mach/CAS into scratchpad	2L	MCDU page changes. Also PFD
		Recall: Task is supported by the automation. Data is defined by clearance. Function is NOT visually salient. CAS or Mach can be entered on CLB page	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recall: valid entries to this field require a 3 digit CAS value. A one to three digit Mach value preceded by a decimal point, a CAS/Mach or a Mach/CAS (within range)	Recog: Labeled XXX SPD	Recog:
5	Delete Speed Transition Altitude	Delete Speed Transition Altitude	VNAV Mode key (Prev or Next)	DELETE in scratchpad	3L	MCDU page changes. Also PFD
Infreq	Allows airplane to accelerate above 250 knots below 10,000 ft	Recall: FMS supports task with SPD TRANS. Data defined by clearance. Function not visually salient. VNAV commanded spds are limited to 250 knts below the Speed Transition Altitude (default 250/10K or as defined for origin airport in the NDB)	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog: Key labeled DELETE	Recog: labeled SPD TRANS	Recog:

6	Enter Speed Restriction	Limit airplane speed in climb to Speed restriction (or speed restriction below speed restriction altitude)	VNAV Mode key (Prev or Next)	Type <speed>/<altitude>	4L	MCDU page changes.
Infreq	If not on departure and in VNAV, pilot will speed intervene	Recall: FMS supports this task with speed restriction function. Data defined by clearance. Function not visually salient.	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recall: valid entries are s digit speed followed by slash followed by altitude. Altitude ,must be above airplane altitude and below CRZ FL	Recog: Label SPD RESTR	Recog:
7	Modify Transition Altitude	Modify Transition Altitude	VNAV Mode key (Prev or Next)	Type altitude into scratchpad	3R	MCDU page changes.
Infreq	In Nav DB, rare to modify	Recall: FMS supports this task with TRANS ALT function. Data defined by clearance. Function not visually salient.	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog: Default format displayed	Recog: labeled TRANS ALT	Recog:
8	Select Max Angle Climb speed	Select Max Angle Climb speed	VNAV Mode key (Prev or Next)	Down-select speed in 4r into scratchpad	4R	MCDU page changes. Also PFD
Infreq	Note: Most pilots will use Speed Intervention	Recall: FMS supports this task with computation of optimum max angle climb speed. Data computed by FMS. Function not visually salient.	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recall: Speed cab down-selected	Recog: labeled XXX SPD	Recog:
9	Activate VNAV Engine-out operation	Activate VNAV Engine-out operation	VNAV Mode key (Prev or Next)	None	5R	MCDU page changes. Also PFD
Infreq		Recall: FMS supports this task. Modifies to engine-out speed schedule, performance predictions, and guidance. Engine-out speed is propagated to T/C and cruise. Data defined by instruction. Function not visually salient.	Recall: Mode key does not reflect task or reformulated task (but repetition)		Recog: Prompt ENG OUT>	Recog:
10	Climb direct to assigned altitude	Climb direct to assigned altitude	VNAV Mode key (Prev or Next)	None	6R	MCDU page changes. Also PFD
		Recall: FMS supports task. Data defined by instruction. Function not visually salient. Prompt when clb	Recall: Mode key does not reflect task or reformulated task (but repetition)		Recog: Prompt CLB DIR>	Recog:

		and alt const exists between cur alt and crz alt. Sel prompt results in del of alt constrs upto the MCP Alt. Alt constr at MCP Alt is not deleted. Spd restriction, Spd limit not affected.				
11	Request data uplink of wind for descent forecast	Request data uplink of wind for descent forecast	LEGS Mode Key. RTE DATA> prompt.	None	6R	MCDU page changes
Infreq	Wind data improves accuracy of predictions	Recall: FMS Supports this task. Data defined by instruction. Function not visually salient. Wind data can be uplinked from the RTE DATA page	Recall: Mode key does not reflect task or reformulated task (but repetition)		Recog: Prompt labeled RTE DATA> and prompt labeled WIND DATA REQUEST >	Recog:
12	Enter Wind data for descent forecast	Enter Wind data for descent forecast at waypoints	LEGS Mode Key. RTE DATA> prompt. Select XR for wind for wpt.	Type altitude as FL. Type <direction in degrees>/<speed in knots>	1l-4l for altitude. 1R - 4R for direction/speed	MCDU page changes
	Wind data improves accuracy of predictions	Recall: FMS supports task. Data defined by task. Function not visually salient. Max of 4 alts may be entered at each wpt. The wind effect is applied along the entire route in both directions. Wind dir and spd are entered for specific alts	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog: Format displayed "DIR/SPEED"	Recog: Labeled DIR/SPD	Recog:
13	Fly to ATC specified altitude crossing restrictions	Enter Altitude constraint in flightplan at waypoint	LEGS Mode key	Type <altitude><Desinatin>	1R - 5R	MCDU page changes.
		Recall: FMS supports this task INDIRECTLY via the LEGS page. Data is defined by instruction. Function is visually salient.	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recall: Altitude entries of less than 1000' must be precedded by zeros. A minimum entry of at least 4 digits is required (e.g. 0800). Negative entries must be entered -NNNN. Altitude constrain entries must be less than the CRZ FL. Followed by B for At or Below, A for At or	Recog: predicted values and values from procedures in Nav Data base displayed	Recog:

				Above. "INVALID ENTRY" displayed on scratchpad.		
14	Fly to ATC specified speed crossing restriction	Enter Speed cosntraint in flightplan at waypoint	LEGS Mode key	Type <airspeed>/	1R-5R	MCDU page changes.
		Recall: FMS supports this task via the LEGS page only when Altitude constraint already exist at a waypoint or speed is defined in conjunction with altitude constraint. Data is defined by instruction. Function is visually salient.	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recall: Airspeed entries in 3-digit CAS format in range of 100-400 knots.	Recog: predicted values and values from procedures in Nav Data base displayed	Recog:
15	Modify altitude or speed crossing restriction	Delete Altitude and/or Speed Constraint	LEGS Mode key	Type DELETE using DELETE key	1R-5R	MCDU page changes.
		Recall: FMS supports this task INDIRECTLY via the LEGS page	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog: Key labeled DELETE	Recog: predicted values and values from procedures in Nav Data base displayed	Recog:
16	Intercept course from present position	Enter P/P value. Data is defined by instruction. Function is not visually salient.	LEGS Mode key	Type P/P<heading>	1X before waypoint desired for intercept of inbound course	MCDU page changes.
Infreq		Recall: FMS supports this task Present/Position	Recog: lateral flightplan changes made on LEGS page	Recall: Format P/P<heading>	Recog: waypoints labeled	Recog:
17	Report Progress (Check flight progress)	Report Progress	PROG mode key	None	None	PROG title line on MCDU page
	UAL don't' train as specific task. Total distance matches expected .. In-time/distance to airport for approach	Recog: FMS computes and displays all parameters	Recog: Mode key labeled with Pilot task			Recog: Page labeled with task
18	Position Report	Position Report	PROG Mode key	None	None	

	Company position reports via data-link (ADS on oceanic). If required voice position report or not ADS equipped.	Recog: FMS computes and displays all parameters	Recall: Mode key labeled with Pilot task. Recog: Page prompt labeled			Recog: Page labeled with task
19	Change Basis of Fuel Used Computations used in Performance Predictions	Change Basis of Fuel Used Computations used in Performance Predictions	PROG mode key	None	Press USE promt LS 6L or 6R	Large font
Infreq	Automation derived task. Improves accuracy of predictions. Rarely used in revenue service. Not traned.	Recall: FMS derived task. Data is provided. Function is NOT visually salient. Nor prompt to perform to task.	Recog: Mode key labeled for reformulated task		Recog: prompt labeled "USE"	Recog; Change in size
20	Execute Cruise Step Climb	Use MCP Selected Altitude	MCP Altitude knob	10,000	dial and push MCP Altitude knob	MCP Alt window changes, PFD Alt Bugs, …
	ATC climb maintain new CRZ Fl	Recall: FMS does support this task. Data is defined by instruction. Function is NOT visually salient. All altitude changes occur through manipulation of the MCP Selected Altitude Trained, lots of repetition		Recog: Knob and window have fixed format	Recall: Level change can be activated by pushing the knob. Trained, lots of repetition	Recog: Visual changes on MCP and PFD, …etc
21	Program planned Cruise Step Climb in FMS Flightplan	Enter Step Crz Fl at waypoint on LEGS page for Step Start	LEGS mode key	Type in scratchpad /<Flightlevel>S	right LS	Updated field, updated predictions
Infreq	Shown on CBT. Not in need-to-know. Not that common of a clearance. Cost of training too high.	Recall: FMS does support this task. Data is defined by instruction. Function is NOT visually salient. Entry of steps on LEGS page using Altitude constraint followed by an "S"	Recall: Mode key labeled with Reformulated task	Recall: Format must be memorized. Similar to Altitude constraint entry	Recall: insert where Altitude constraint entry goes	Recog: Changes on LEGS page

22	Lateral route offset	Enter offset on RTE page	RTE Mode key	Type in scratchpad <side L or R><distance>	LS 6R	verify on ND
Infreq	More common during weather. ATC starting to use more often. UAL train in conjunction with CPDLC.	Recall: Task supported by function on RTE page. Offset not available on SIDS, approach, DME arc, heading leg, ...etc. Data provided by instruction. Function is NOT visually salient.	Recog: Mode key labeled for reformulated task	Recall: format <side L or R><distance>	Recog: LS key labeled "OFFSET"	Recog: Verify on ND. Offset displayed as WHITE dashed line on the ND. After execution, magenta line.
23	Direct To	Move waypoint in first line of LEGS	LEGS mode key	Type Waypoint in scratchpad	LS 1L	Verify on ND
	Easiest way to get a clerance from ATC. Flightplan not designed for local winds.	Recall:. Function is supported by the FMS. Data is defined by instruction. Function is not visually salient. Waypoint in 1L is active waypoint. Confusing to people who have used a DIRECT TO button.	Recog; Mode key labeled for reformulated task	Recall: Waypoint Identified (5 character ICAO) must remembered and/or held in long-term memory	Recall: Field not labeled	Recog: Verify on ND
24	Intercept course to a fix	Move waypoint in first line of LEGS and enter INTC COURSE TO on LEGS page	LEGS mode key	Type Waypoint in scratchpad AND enter Intercept course	LS 1L and LS 6R	verify on ND
Infreq	ATC clearance: Cleared to intercept ABC 180 degree radial and track to the VOR. Course intercept to a waypoint is label of LEGS page.	Recall:. Waypoint in 1L is active waypoint. Data MAY be defined or MAY Need to calculate the reverse course to ... Function is not visually salient.	Recog: Mode key labeled for reformulated task	Recall: Waypoint Identified (5 character ICAO) must remembered and/or held in long-term memory. Also intercept course must be held in Working memory	Recall: Field not labeled	Recog: Verify on ND
25	Intercept course FROM a fix	Enter waypoint/course into 1L on the LEGS page	LEGS mode key	Type <wyapoint ident><course>	LS 1L	Verify on ND

Infreq	Only place used Paris. No limit for loss radio contact. Use track mode on MCDU (rare), put track on the FIX page and track with MCP heading select. (also NAV RAD page). Confused with intercept to a course.	Recall: Function is supported by the FMS - Waypoint followed by course in 1L is entry for task. Data is defined by instruction. Function is NOT visually salient.	Recog: Mode key labeled for reformulated task	Recall: format <waypoint ident><course>	Recall: Field not labeled	Recog: Verify on ND
26	Copy route	Copy route from RTE page	RTE Mode key	None	LS 4R	Verify on RTE page
Infreq	Automation derived task	Recog:	Recog; Mode key labeled for task		Recog: labeled "RTE COPY"	Recog; labeled "RTE COPY COMPLETE"
27	Modify CRZ ALT	Enter CRZ ALT on CRZ page	VNAV Mode key (Prev or Next)	Type flightlevel	LS 1L	Verify entry on CRZ page
	Automation derived task to improve accuracy of predictions. Change CRZ ALT especially when CRZ FL lowered (does not automaticaly bump CRZ FL)	Recog: Crz profile and performance adjusted on CRZ page	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog; Format supported by existing entry	Recog; labeled "CRZ ALT"	Recog: Verify on CRZ page
28	Modify cruise STEP SIZE to enable accurate predictions	Enter desired step size on CRZ page	VNAV Mode key (Prev or Next)	Type step size in 1000's of feet	LS 4L	Verify entry on CRZ page
Infreq	Automation derived task to improve accuracy of predictions. Not critical, cos does not change	Recall: Need to understand Crz Step Size. Don't know for sure whether climb will occur and need to know fuel at destination. Recog: Crz profile and performance adjusted on CRZ page. Function supported by	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog; Format supported by existing entry	Recog; labeled "STEP SIZE"	Recog: Verify on CRZ page

	predictions that much.	FMS. Data is defined by instruction. Function not visually salient.				
29	Modify criuse STEP TO altitude to enable accurate predictions	Enter desired altitude on CRZ page	VNAV Mode key (Prev or Next)	Type altitude in scratchpad	LS 1R	Verify on CRZ page
Infreq	Automation derived task to improve accuracy of predictions	Recall: Function supported by FMS. Data is defined by instruction. Function is NOT visually salient. Need training to understand what this is and how it works. Recog: Crz profile and performance adjusted on CRZ page	Recall: Mode key does not reflect task or reformulated task (but repetition)	Recog: Format supported by existing entry	Recog; labeled "STEP TO"	Recog: Verify on CRZ page
30	Activate ENG OUT to enable VNAV, LNAV, LEGS page, predictions changes	Engine-out may be activated on CRZ page	VNAV Mode key (Prev or Next)	None	LS 5R	Verify on CRZ page, ND, ...etc.
Infreq		Recall: Function derived by Engine-out may be activated on CRZ page. Data defined by instruction. Function NOT visually salient (unless by scratchpad message)	Recall: Mode key does not reflect task or reformulated task (but repetition)		Recog; Labeled "ENG OUT"	Recog: Lots of visual cues
31	Activate Long-range Cruise Speed for VNAV and predictions	LRC may be activated on CRZ page	VNAV Mode key (Prev or Next)	None	LS 6R	verify on CRZ page and PFD
Infreq		Recall: Function is supported by the FMS. Data is defined by instruction. Function is not visually salient. Crz profile and performance adjusted on CRZ page	Recall; Mode key does not reflect task or reformulated task (but repetition)		Recog: labeled "LRC"	Recog: Verify on CRZ page and on PFD

32	Enter Hold at Fix on path	Enter Fix in HOLD AT on LEGS page	HOLD Mode key	Type waypoint into scratchpad (or pull down ident into scratchpad)	LS 6L	Verify on ND and HOLD MCDU page
		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. Holds are entered on Hold page	Recog: Mode key labeled for task	Recog:	Recog: Labeled "HOLD AT"	Recog:
33	Enter Hold at Present Position	Use Hold at PPOS function	HOLD Mode key	None	LS 6R	Verify on ND and HOLD MCDU page
		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. Holds at PPOS are entered on Hold page	Recog: Mode key labeled for task		Recog:	Recog:
34	Exit Hold	Use EXIT HOLD function	HOLD Mode key	None	LS 6R	Verify on ND and HOLD MCDU page. EXIT ARMED displayed in 6R under certain conditions
		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. Holds at PPOS are entered on Hold page	Recog: Mode key labeled for task		Recog:	Recog:
35	Enter Quad/Radial for Hold	Enter Quad/Radial for Hold	HOLD Mode key	Type into scratchpad	LS 2L	Verify on ND and HOLD MCDU page
Infreq		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. All hold properties available on Hold page	Recog: Mode key labeled for task	**Recall: <quadrant>/<3 digit radial> OR /<3 digit radial> OR <3 digit radial>. Legal quadrants N, NE, E, SE, S, SW, W, NW.**	Recog: Labeled "QUAD/RADIAL"	Recog:
36	Enter Inbound Course/Turn Direction for Hold	Enter Inbound Course/Distance for Hold	HOLD Mode key	Type into scratchpad	LS 3L	Verify on ND and HOLD MCDU page
Infreq		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. All hold properties available on	Recog: Mode key labeled for task	Recog: Format displayed withdefault entries <degrees>/<L or R>	Recog: Labeled INBD CRS/DIR	Recog:

		Hold page				
37	Enter LEG TIME for Hold	Enter LEG TIME for Hold	HOLD Mode key	Type into scratchpad	LS 4L	Verify on ND and HOLD MCDU page
Infreq		Recog: All hold properties available on Hold page	Recog: Mode key labeled for task	Recog: Format displayed with default entries 1.5 mins above 14,000' or 1.0 mins below 14,000'	Recog: Labeled LEG TIME	Recog:
38	Enter LEG DIST for Hold	Enter LEG DIST for Hold	HOLD Mode key	Type into scratchpad	LS 5L	Verify on ND and HOLD MCDU page
Infreq		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. All hold properties available on Hold page	Recog: Mode key labeled for task	Recog: Format displayed	Recog: Labeled LEG DIST	Recog:
39	Enter Expect Further Clearance Time (EFC) for Hold	Enter Expect Further Clearance Time (EFC) for Hold	HOLD Mode key	Type into scratchpad	LS 6L	Verify on ND and HOLD MCDU page
Infreq		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. All hold properties available on Hold page	Recog: Mode key labeled for task	Recog: Format displayed by predictions for exit after first hold 9also standard Zulu Time format)	Recog: Labeled EFC TIME	Recog:
40	Enter Speed/Altitude Target Constraint at Hold Fix	Enter Speed/Altitude Target Constraint at Hold Fix	HOLD Mode key	Type into scratchpad	LS 1R	Verify on ND and HOLD MCDU page
Infreq		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. All hold properties available on Hold page	Recog: Mode key labeled for task	Recall: <3 digits>/<3 to five digits below Crz FL>	Recog: Labeled SPD/TGT ALT	Recog:
41	Enter Speed/Altitude Target Constraint at Hold Fix	Enter Speed/Altitude Target Constraint at Hold Fix	HOLD Mode key	Type into scratchpad	LS 1R	Verify on ND and HOLD MCDU page

Infreq		Recog: FMS supports the task. Data is defined by instruction. Function is visually salient. All hold properties available on Hold page	Recog: Mode key labeled for task	Recall: /<3 to five digits below Crz FL>	Recog: Labeled SPD/TGT ALT	Recog:
42	Remove ROUTE DISCONTIUITY before exiting the HOLD	Remove ROUTE DISCONTIUITY before exiting the HOLD on the LEGS page	LEGS mode key	Type Ident into scratchpad	LS 2L	Verify on ND and HOLD MCDU page
	Automation derived task to ensure validity of next fix.	Recog: Automation derived task to ensure validity of next fix. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Reformaulated task requires use of LEGS	Recog: next waypoint on LEGS page or other clearance	Recog: Labeled "THEN" and boxed entry	Recog:
43	Create fix or waypoint from intersection between flightplan and selected radial.	Create fix or waypoint from intersection between flightplan and selected radial	FIX Mode key	Type radial into scratchpad	LS 2L, 3L, 4L	Verify on ND and MCDU FIX page
Infreq		Recog: All Fix info is available on the FIX INFO page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task	Recall: <3 digits ranging from 000 to 360 degrees>	Recog: Labeled "BRG/DIS"	Recog:
44	Create fix or waypoint from intersection between flightplan and selected distance	Create fix or waypoint from intersection between flightplan and selected distance	FIX Mode key	Type distance into scratchpad	LS 2L, 3L, 4L	Verify on ND and MCDU FIX page
Infreq		Recog: All Fix info is available on the FIX INFO page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task	Recog: /<distance>	Recog: Labeled "BRG/DIS"	Recog:
45	Create fix or waypoint from intersection between flightplan and	Create fix or waypoint from intersection between flightplan and selected radial/distance	FIX Mode key	Type radial/distance into scratchpad	LS 2L, 3L, 4L	Verify on ND and MCDU FIX page

	selected radial/distance					
Infreq		Recog: All Fix info is available on the FIX INFO page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task	Recog: <3 digits ranging from 000 to 360 degrees>/<distance>	Recog: Labeled "BRG/DIS"	Recog:
46	Show Fix on ND	Show Fix on ND	FIX Mode key	Type Ident in scratchpad	LS 1L	Verify on ND and MCDU FIX page
		Recog: All Fix info is available on the FIX INFO page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task	Recall: ICAO identifier for waypoint or fix	Recog: labeled FIX with boxes for entry	Recog:
47	Show ABEAM Point on Flightplan to FIX	Show ABEAM Point on Flightplan to FIX	FIX Mode key	None	LS 5L	Verify on ND and MCDU FIX page
Infreq		Recog: All Fix info is available on the FIX INFO page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task		Recog: Prompt labeled "<ABEAM".	Recall: if an abeam point cannot be computed on the flightplan INVALID ENTRY is displayed.
48	Compute fix crossing point for ETA	Compute fix crossing point for ETA	FIX Mode key	Type ETA into scratchpad	LS 6R	Verify on MCDU FIX page
Infreq		Recog: Fix crossing point can be computed for an ETA entry on FIX page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for reformulated task	Recall: <four digits>Z	Recog: labeled PRED ETA-ALT	Recog:
49	Compute fix crossing point for Altitude	Compute fix crossing point for Altitude	FIX Mode key	Type Altitude into scratchpad	LS 6R	Verify on MCDU FIX page
Infreq		Recog: Fix crossing point can be computed for an Altitude entry on FIX page. FMS supports the task. Data is defined by instruction. Function is	Recog: Mode key labeled for reformulated task	Recall: <fthree to five digits>	Recog: labeled PRED ETA-ALT	Recall: If predicted fix does not occur on the flight path display remains blank

		visually salient.				
50	Look-up Frequency and Lat/Lon of waypoint	Look-up Frequency and Lat/Lon of waypoint	INIT REF Mode key	Type waypoint, naviad, airport ordestination runway (in Nav Data base)	LS 1L	Verify on MCDU REF NAV DATA page
Infreq		Recog: Navigation data can be accessed on the REF NAV DATA page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task	Recall: ICAO identifier for waypoint or fix AND that it is in the Nav Data base	Recog: labeled IDENT	Recog;
51	Inhibit upto 2 VORs in the Nav data Base from being used for Aircraft Position Computation	Inhibit upto 2 VORs in the Nav data Base from being used for Aircraft Position Computation	INIT REF Mode key	Type naviad into scratchpad	LS 5L and 5R	Verify on MCDU REF NAV DATA page
Infreq	Automation derived task to improve accuracy of FMS computations	Recog: Navigation data can be accessed on the REF NAV DATA page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task	Recall: ICAO identifier for waypoint or fix AND that it is in the Nav Data base	Recog: Labeled VOR ONLY INHIBIT	Recog;
52	Inhibit upto 2 VORSs, VOR/DMEs, VORTACs, or DMES in the Nav Data base from beingused for Aircraft Position computation	Inhibit upto 2 VORSs, VOR/DMEs, VORTACs, or DMES in the Nav Data base from being used for Aircraft Position computation	INIT REF Mode key	Type naviad into scratchpad	LS 4L and 4R	Verify on MCDU REF NAV DATA page
Infreq	Automation derived task to improve accuracy of FMS computations	Recog: Navigation data can be accessed on the REF NAV DATA page. FMS supports the task. Data is defined by innstruction. Function is visually salient.	Recog: Mode key labeled for task	Recall: ICAO identifier for waypoint or fix AND that it is in the Nav Data base		Recog;

53	Change use of VOR/DME data for Aircraft Position Computation	Use VOR/DME NAV ON/OFF switch	INIT REF Mode key	None	LS 6R	Verify on MCDU REF NAV DATA page
Infreq	Automation derived task to improve accuracy of FMS computations	Recog: Navigation data can be accessed on the REF NAV DATA page. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog: Mode key labeled for task		Recog: Labeled VOR/DME NAV - OFF<->ON	Recog;
54	SELECT DESIRED WAYPOINT from duplicates in the Nav Data Base	SELECT DESIRED WAYPOINT from duplicates in the Nav Data Base	Automatically displayed following entry of Ident with duplicate in the Nav Data Base	None	LS 1l - XL or 1R - XR	None
	Automation derived task to improve accuracy of pilot entries	Recog: MCDU displays page automatically if duplicates exist. FMS supports the task. Data is defined by instruction. Function is visually salient.	Recog:		Recog: Labeled	
55	Enter forecast wind speed and direction to improve accuracy of descent path and predictions	Enter forecast wind speed and direction to improve accuracy of descent path and predictions	VNAV Mode key, (Next if not in Descent), 5R FORECAST prompt	Type wind direction/speed in scratchpad	LS 2R - 5R	Verify on MCDU DESCENT FORECAST page
Infreq	Automation derived task to improve accuracy of FMS computations	Recall: FMS supports task. Data is defined by instruction. Function is NOT visually salient. Wind entries can be entered on the DESCENT FORECAST page	Recall: DESCENT FORCECAST page is accessed from the DES page	Recall: <wind dierction in True and 3 digits. Leading zeros reqiured>/<knots 1 to 3 digits between 0 and 250>. Subsequent entries may be partial.	Recog: labeled WIND DIR/SPD	Recog:
56	Adjust TRANSITION LEVEL for descent phase of flight from defualt FL180 for VNAV guidance and	Adjust TRANSITION LEVEL for descent phase of flight from defualt FL180 for VNAV guidance and predictions	VNAV Mode key, (Next if not in Descent), 5R FORECAST prompt	Type flightlevel into scratchpad	LS 1L	Verify on MCDU DESCENT FORECAST page

	predictions					
Infreq	Automation derived task to improve accuracy of FMS computations	Recall: Transition Altitude can be changed on the DESCENT FORECAST page. FMS supports task. Data is defined by instruction. Function is NOT visually salient.	Recall: DESCENT FORCECAST page is accessed from the DES page	Recog: Format displayed for default FL180. Format for entry is FL<1 to 3 digits>	Recog: Labeled TRANS LVL	Recog:
57	Request data link of Descent Wind data	Request data link of Descent Wind data	VNAV Mode key, (Next if not in Descent), 5R FORECAST prompt	None	LS 6L	Verify on MCDU DESCENT FORECAST page
	Automation derived task to improve accuracy of FMS computations	Recall: Automation derived task. Wind entries can be entered on the DESCENT FORECAST page. FMS supports task. Data is defined by instruction. Function is NOT visually salient.	Recall: DESCENT FORCECAST page is accessed from the DES page		Recog: Labeled FORECAST <REQUEST	Recog:
58	Initiate Descent at T/D	use MCP Selected Altitude	MCP Altitude knob	Dial altitude clearance into the window	dial and push MCP Altitude knob	MCP Alt window chnages, PFD Alt Bugs, …
Infreq	Recog: MCDU scratchpad message "RESET MCP ALT" is displayed 2 minutes before T/D (if MCP Alt is not aleady dialed down)	Recall:. Task is supported by the FMS. Data is defined by instruction. Function is NOT visually salient - All altitude changes occur through manipulation of the MCP Selected Altitude Trained, lots of repetition.		Recog: Knob and window have fixed format	Recall: Level change can be activated by pushing the knob. Trained, lots of repetition	Recog: Visual chnages on MCP and PFD, …etc
59	Modify Descent Mach or CAS	Change Mach/CAS values on DES page	VNAV Mode key	Type CAS/mach in scratchpad	LS 2L	MCDU page, PFD changes
Infreq		Recall: Task is supported by FMS- DES page includes all information related to descent performance. Data is defined by instruction. Function is NOT visually	Recall: Mode key labeled for reformulated task	Recall: <Cas 3 digits>/<mach>	Recog: Labeled XXX SPD	Recog:

		salient.				
60	Modify Speed Transition (e.g. 250/FL100)	Modify Speed Transition	VNAV Mode key	Type CAS/altitude	3L	MCDU page change
Infreq		Recall: Task is supported by the FMS. Descent profile is determined by Speed Transition and this is available on the DES page. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task	Recog: format displayed in 3L	Recog: Labeled SPD TRANS	Recog:
61	Modify Speed Restriction	Modify Speed Restriction	VNAV Mode key	Type CAS/altitude	4L	MCDU page change
Infreq		Recall: Function is supported by FMS. Descent profile determined by parameters on DES page. Altitude must be below the CRZ FL, below aircraft alt, and above E/D Alt (see 1L). Airspeed must be less than CAS of the first remaining descent segment and 100-400. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task	Recog: format displayed in 4L	Recog: Labeled "SPD RESTR"	Recog:
62	Delete Altitude constraint at next waypoint with an altitude constraint	Delete Altitude constraint at next waypoint with an altitude constraint	VNAV Mode key	DELETE in scratchpad	1R	MCDU page change
Infreq		Recall: Task is supported by FMS - Descent profile determined by parameters on DES page. Can only be deleted on DES page. Also see LEGS page. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task	Recall: To delete an entry select the "delete" button to get the DELETE in the scratchpad.	Recog: Labeled "AT <waypoint name>"	Recog:
63	Descend Direct	Descend Direct	VNAV Mode key	None	6R	MCDU page changes. Also may see changes on ND and PFD

Infreq	Cleared to MCP Altitude below existing descent altitude constraints in the flightplan	Recall: Task is supported by FMS - DES page. Data is defined by instruction. Function is NOT visually salient.	Recog: Mode key labeled for reformulated task		Recog: Labeled DES DIR>	Recog:
64	Descend Now	Descend Now	VNAV Mode key	None	6R	MCDU page changes. Also may see chnages on ND and PFD
Infreq	Cleared to descend when aircraft is in Cruise (not already in descent)	Recall: Task is supported by the FMS - DES page deletes all climb and descent constraint and initiates an early descent before reaching T/D. Flightpath trajectory follows a 1250 fpm descent with THR HOLD to allow pilot to adjust rate-of-descent. Until intercepting optimum VNAV path. Data is defined by instruction. Function is NOT visually salient.	Recog: Mode key labeled for reformulated task		Recog: Labeled DES DIR>	Recog:
65	Display DTG to E/D or other waypoint	Display DTG to E/D or other waypoint	VNAV Mode key. OFFPATH DES prompt in 6L	Type ICAO ident for waypoint in scratchpad	1L	MCDU page changes.
Infreq	Part of larger problem solving task	Recall: OFFPATH DES page supports this task. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task	Recall: ICAO ident (may be in flightplan)	Recog: Labeled DES TO	Recog:
66	Modify descent speed	Change descent speed.	VNAV Mode key. OFFPATH DES prompt in 6L	Type Mach/CAS, Mach or CAS	2L	MCDU page changes.
Infreq	ATC instruction to modify speed	Recall: OFFPATH DES page supports this task. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task	Recog: default ECON entries define format	Recog: Labeled 2L	Recog:
67	Modify Speed Transition (e.g. 250/FL100)	Modify Speed Transition	VNAV Mode key. OFFPATH DES prompt in 6L	Type CAS/altitude	3L	MCDU page change
Infreq		Recall: Descent profile is determined by Speed Transition and this is available on the DES page.	Recall: Mode key labeled for reformulated task	Recog: format displayed in 3L	Recog: Labeled SPD TRANS	Recog:

		Data is defined by instruction. Function is NOT visually salient.				
68	Modify Speed Restrication	Modify Speed Restrication	VNAV Mode key. OFFPATH DES prompt in 6L	Type CAS/altitude	4L	MCDU page change
Infreq		Recall: Descent profile determined by parameters on DES page. Altitude must be below the CRZ FL, below aircraft alt, and above E/D Alt (see 1L). Airspeed must be less than CAS of the first remaining descent segment and 100-400. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task	Recog: format displayed in 4L	Recog: Labeled "SPD RESTR"	Recog:
69	Return to ECON speed	Return to ECON speed	VNAV Mode key. OFFPATH DES prompt in 6L	None	5L	MCDU page change. Also PFD and ND
Infreq	ATC instruction	Recall: OFFPATH DES page supports this task. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task		Recog Prompt <ECON	Recog:
70	Display Distance from aircraft to optimum VNAV path Clean and Drag on ND	Display Distance from aircraft to optimum VNAV path Clean and Drag on ND	VNAV Mode key. OFFPATH DES prompt in 6L	None	6R	MCDU page change. ND change
	Part of larger problem solving task	Recall: OFFPATH DES page supports this task. Data is defined by instruction. Function is NOT visually salient.	Recall: Mode key labeled for reformulated task		Recog: Labeled DISPLAY OFF<->ON	
71	String STAR into the Route	String STAR into the Route	DEP ARR Mode key	None	XL	MCDU page change
		Recall: Task supported on ARRIVALS page. Data is defined by instruction. Function is visually salient.	Recog: DEP ARR Mode key		Recog: Item in list	
72	String Approach into the Route	String Approach into the Route	DEP ARR Mode key	None	XR	MCDU page change

		Recall: Task supported on ARRIVALS page. Data is defined by instruction. Function is visually salient.	Recog: DEP ARR Mode key		Recog: Item in list	
73	String Transition into Route	String Transition into Route	DEP ARR Mode key	None	XR	MCDU page change
Infreq		Recall: Task supported on ARRIVALS page. Data is defined by instruction. Function is visually salient.	Recog: DEP ARR Mode key		Recog: Item in list	
74	Intercept approach fix or runway	Intercept approach fix or runway	DEP ARR Mode key	None	6R	MCDU page change. ND page change
	ATC cleared for approach	Recall: Task supported on ARRIVALS page. Function is enabled for: all published and tailored approaches in the nav data base for selected destination airport, all runways with VFR approach, all runways with entered Runway extension fix, arrivals with only the runway selected. Also auto-tunes the ILS frequency (if ILS tuning mode is Auto). Data is defined by instruction. Function is visually salient.	Recog: DEP ARR Mode key		Recog: Labeled APPROACH INTERCEPT	
75	VFR Approach with LNAV and VNAV	VFR Approach with LNAV and VNAV	DEP ARR Mode key	None	6R	MCDU page change. ND page change
Infreq		Recall: task supported on ARRIVALS page. Creates a path in-line with the runway center-line beginning with a point 50 feet above the runway threshold and extending upward at the specified flight path angle until it intercepts a plane 2000 feet above the runway threshold. Guidance is provided to arrive at the FAF at 170 knots. Data is defined by instruction. Function is visually salient.	Recog: DEP ARR Mode key		Recog: Labeled VFR APPROACH	

76	Modify FPAngle for VFR Approach	Modify FPAngle for VFR Approach	DEP ARR Mode key	Type FPAngle	XX	MCDU Change
Infreq		Recall: Task supported on ARRIVALS page. The path is constructed from 50ft above the runway threshold at the specified angle to 2000 ft. It then remains level at 2000' until 8nm from the runway threshold. Data is defined by instruction. Function is visually salient.	Recog: DEP ARR Mode key	Recall: limited to between 2.4 degrees and 3.7 degrees	Recog: Labeled FPA	Recog:
77	Create fix on Runway extension line at specified distance	Create fix on Runway extension line at specified distance	DEP ARR Mode key	Type distance nm from runway threshold	3R	MCDU Change
Infreq	Runway Extension Fix imprtoves accuracy of predictions. Guidance ?	Recall: Task supported on ARRIVALS page. Applies only for runway selected without an approach procedure. Data is defined by instruction. Function is visually salient.	Recog: DEP ARR Mode key	Recall: valid entries one or two digit entries followed by tenths ranging from 1.0 to 25.0	Recog: Labeled RWY EXT	Recog:
78	Recapture the optimum VNAV path with DRAG or THRUST	Recapture the optimum VNAV path with DRAG or THRUST	Find drag and thrust levers	None	Move	Aircarft trajectory chnages
	Aircraft reaches limit speed (e.g. due to tailwind) and departs the path, needs to add drag or thrust to return to path	Recog; DRAG REQUIRED or THRUST REQUIRED messages. Data N/A. Function IS salient.	Recall	None	Recall: Mode determines impact	Recog:
79	Select Alternate Airport	Select Alternate Airport	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	None	XL	<A> or <SEL> displayed next to selected airport
Infreq		Recall: Automation supports this task. Data is defined by task. Function is NOT visually salient.	Recog: ALTN Mode key		Recog: LS ket selects item from list	

80	Manually enter Alternate airport	Manually enter Alternate airport	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	Type airport ident into scratchpad	XL	Large font
Infreq		Recall: Automation supports this task. Data is defined by task. Function is NOT visually salient.	Recog: ALTN Mode key	Recall: Airport ICAO ident	Recog:	Recog:
81	Delete manually entered alternate airports from ALTN page	Delete manually entered alternate airports from ALTN page	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	Place "DELETE" in scratchpad	XL	Airport ident replaced by on from Nav Data-base. Small font
Infreq		Recall: Automation supports this task. Data is defined by task. Function is NOT visually salient.	Recog: ALTN Mode key	Recog: Key labeled DELETE	Recog:	Recog:
82	Request data-link of preferred list of alternates (upto 4)	Request data-link of preferred list of alternates (upto 4)	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	None	5L	Label changes
Infreq		Recall: Automation supports this task. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key		Recog: labeled <ALTN REQUEST	Recog:
83	Request data-link of Weather for alternate airport	Request data-link of Weather for alternate airport	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	None	6L	Label changes
Infreq		Recall: Automation supports this task. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key		Recog: labeled <WXR REQUEST	Recog:
84	Display non-selected Alternate airports on the ND in Map mode	Display non-selected Alternate airports on the ND in Map mode	EFIS Control Panel	None	ARPRT Switch to ON	Alternate airports displayed on ND
Infreq		Recall: Automation supports this task - EFIS Control Panel Airports switch activates display of	Recog: contents of ND controlled by config of panel		Recog: Switch labeled ARPRT	Recog:

		Alternate airports (in addition to airports within range). Data is defined by instruction. Function is NOT visually salient.				
85	Inhibit airports in Nav Data-base from display on ALTN page	Inhibit airports in Nav Data-base from display on ALTN page	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	Type ICAO ident / ICAo ident in scratchpad	5R	Change in MCDU page
Infreq		Recall: Automation supports this task. EFIS Control Panel Airports switch activates display of Alternate airports (in addition to airports within range). Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key	Recog: ICAo ident / ICA ident	Recog: Labeled ALTN INHIBIT	Recog:
86	Modify route from present position to selected Alternate	DIVERT NOW	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	None	6R	ND changes route to destination. Scratchpad message, DESCENT PATH DELETED (if descent path exists)
Infreq		Recall: Automation changes route to destination airport, incorporates route modification into the active flightplan, deletes all parts of route that are not part of the diversion, deletes all descent constraints in flightplan for descent path. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key		Recog: Labeled DIVERT NOW	Recog:
87	Delete entire list of Alternate airports	PURGE Alternate airport list	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM	None	5R then CONFIRM	Change in MCDU page
Infreq		Recall: List can be purged. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key		Recog: Labeled PURGE, then CONFIRM	Recog:

88	Direct To selected Alternate airport	Direct To selected Alternate airport	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM then DIVERT NOW prompt	None	1L	Change in MCDU page
Infreq		Recall: Automation supports direct to destination. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key, then DIVERT NOW prompt		Recog: Labeled DIRECT TO	Recog:
89	Lateral offset to the current active route	Lateral offset to the current active route	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM then DIVERT NOW prompt	Type side and offset distance	2L	Change in MCDU page
Infreq		Recall: Automation supports direct to destination. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key, then DIVERT NOW prompt	Recog: default entry of L00	Recog: labeled L00 Offset	Recog:
90	Active route to diversion waypoint	Active route to diversion waypoint	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM then DIVERT NOW prompt	Type diversion waypoint ICAO ident in scratchpad	3L	Change in MCDU page
Infreq		Recall: FMS supports task. Data is defined by instruction. Function is NOT visually salient. Follow current active route until overhead diversion waypoint, then follow route to alternate airport. Deleted all waypoints from the original active flightplan except those waypoints between PPOS and diversion waypoint.	Recog: ALTN Mode key, then DIVERT NOW prompt	Recall: ICAO ident	Recog: labeled OVERHEAD	Recog:
91	Enter estimated Wind for diversion route	Enter estimated Wind for diversion route	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM then DIVERT NOW prompt	Type direction in degrees / magnitude	3R	Change in MCDU page
Infreq	Improves accuracy of predicted ETA and Fuel	Recall: FMS supports task. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key, then DIVERT NOW prompt	Recog: format prompted. Valid entry direction in degrees, speed in knots 1 to 999	Recog: labeled WIND DIR/SPD	Recog:

92	Enter OAT for altitude	Enter OAT for altitude	ALTN Mode key, or <ALTN prompt on RTE1/X, INIT REF/INDEX, FMC COMM then DIVERT NOW prompt	Type altitude/ temperature	4R	Change in MCDU page
Infreq	Improves accuracy of predicted ETA and Fuel	Recall: FMS supports task. Data is defined by instruction. Function is NOT visually salient.	Recog: ALTN Mode key, then DIVERT NOW prompt	Recog: format prompted. Valid entry temp in degrees C	Recog: labeled ALT/OAT	Recog:
93	Tune VOR or DME	Enter VOR or DME identifiers, or VOR frequency/course	NAV RAD Mode key	Type VOR or DME ident in scratchpad, or Type frequency/course in scratchpad. Item may be pulled-down from preselect 6L or 6R	1L or 1R	Change in MCDU page
		Recog: FMS supports this task - radios can be tuned via the NAV RAD MCDU page. Data is defined by instruction. Function IS visually salient.	Recog: NAV RAD mode key	Recog: idents, frequency, course from charts or ATC	Recog: Labeled VOR or DME	Recog: Visual changes on MCDU and ND
94	Revert from manual tuning to Auto tuning	Delete manually entered VOR, or DME idents, freq/course	NAV RAD Mode key	Type DELETE key in scratchpad	1L or 1R	Change in MCDU page
		Recog: radios can be tuned via the NAV RAD MCDU page. Data is defined by instruction. Function IS visually salient.	Recog: NAV RAD mode key	Recog: DELETE key	Recog: Labeled VOR or DME	Recog: Visual changes on MCDU and ND
95	Display Course/Radial of ND	Enter Course/Radial	NAV RAD Mode key	Type course or VOR ident/course. Item may be pulled-down from preselect 6L or 6R	2L or 2R	Change in MCDU page
		Recall: Course/radial can be displayed on ND following entry in NAV RAD page. Data is defined by instruction. Function is NOT visually salient.	Recog: NAV RAD mode key	Recall: <ident>/<Course>	Recog: Label CRS and RADIAL	Recog: Visual chnages on MCDU and ND
96	Delete Display of Course Radial	Delete manually entered CRS	NAV RAD Mode key	Type DELETE key in scratchpad	2L or 2R	Change in MCDU page
		Recog: delete entry. Data is defined by instruction. Function IS visually salient.	Recog: NAV RAD mode key	Recog: DELETE key	Recog: Label CRS and RADIAL	Recog: Visual changes on MCDU and ND

97	Tune ADF	Enter ADF frequency	NAV RAD Mode key	Type ADF frequency into scratchpad. Item may be pulled-down from preselect 6L or 6R	3L or 3R	Change in MCDU page
.		Recog: ADF can be tuned via MCDU NAV RAD page. Data is defined by instruction. Function IS visually salient.	Recog: NAV RAD mode key	Recall: Valid entries are three or four digit values optionally followed by a decimal point and tenths digit. The ADF frequency may optionally be followed "A" (for ANT mode) or "B" (for BFO mode).	Recog: Label ADF L, ADF R	Recog: Visual chnages on MCDU and ND
98	Tune ILS-MLS	Enter ILS frequency and front course, (or MLS channel and azimuth)	NAV RAD Mode key	Type ILS frequency/front course, or front course if frequency already entered, or MLS Channel/azimuth in scratchpad. Item may be pulled-down from preselect 6L or 6R	4L or 4R	Change in MCDU page
Infreq		Recog: ILS-MLS can be tuned via the MCDU NAV RAD page. Recall: ILS Recievers are inhibitted from manual tuning when: (1) autpilot engaged localizer or glideslope is captured, F/D no autopilot and localizer/glideslope captured and below 500ft RA, on ground and localizer alive with airplane heading within 45 deg of loc front course and groundspeed greater than 40 knots. Manual tuning is restored when wither TOGA switch is pushed, Autopilot is disengaged and bot F/D are off, or MCP Approach switch is deselected when airplane above 1500 ft. Data is defined by instruction. Function IS visually salient.	Recog: NAV RAD mode key	Recog: format	Recog: label ILS-MLS	Recog: Visual changes on MCDU and ND

99	Enter Approach page GW	Enter Approach page GW	INIT REF Mode key	Weight in thousands of pounds or thousands of kilograms	1L	MCDU page changes
Infreq	Pilot entered GW are for approach reference speed computation only	Recall: GW entry for Approach speed computation only. Data is defined by instruction. Function is NOT visually salient.	Recall: INIT REF key when aircraft is airborne	Recall: Weight in thousands of pounds or thousands of kilograms, based OPC option	Recog: Labeled GROSS WT	Recog:
100	Change Landing Reference	landing Ref modified on APPROACH page	INIT REF Mode key	None	3L	MCDU page changes
		Recall: Landing Ref modified on APPROACH page. Data is defined by instruction. Function is NOT visually salient.	Recall: INIT REF key when aircraft is airborne		Recog: Labeled LANDING REF <QFE <-->QNH	Recog:
101	Display VREF speeds on PFD speed tape	Display VREF speeds on PFD speed tape	INIT REF Mode key	Down-select (or type) speed or flap setting/speed in scratchpad	4R	MCDU page changes
		Recall: down-selecting VREF speeds 1R, 2R, 3R into 4R displays speed on speed tape. Data is defined by instruction. Function is NOT visually salient.	Recall: INIT REF key when aircraft is airborne	Recog: Default format displayed	Recog: Labeled FLAP/SPEED	Recog:
102	Display localizer radio updating and localizer identifier for this approach	Display localizer radio updating and localizer identifier for this approach	INIT REF Mode key, 6L INDEX, 2L POS, Next Page	None	None	MCDU page changes
Infreq		Recall: Displayed on POS REF 2/3. Data is defined by instruction. Function is NOT visually salient.	Recall/Recog: see above			Recog:

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13. ABSTRACT *(Maximum 200 words)*

The Flight Management Computer (FMC) and its interface, the Multi-function Control and Display Unit (MCDU) have been identified by researchers and airlines as difficult to train and use. Specifically, airline pilots have described the “drinking from the fire-hose” effect during training. Previous research has identified memorized action sequences as a major factor in a user’s ability to learn and operate complex devices.

This paper discusses the use of a method to examine the quantity of *memorized action sequences* required to perform a sample of 102 tasks, using features of the Boeing 777 Flight Management Computer Interface. The analysis identified a large number of memorized action sequences that must be learned during training and then recalled during line operations. Seventy-five percent of the tasks examined require recall of at least one memorized action sequence. Forty-five percent of the tasks require recall of a memorized action sequence and occur infrequently. The large number of memorized action sequences may provide an explanation for the difficulties in training and usage of the automation. Based on these findings, implications for training and the design of new user-interfaces are discussed.

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